DEVELOPMENT OF OBJECTIVE TESTS FOR AUTOMATED VEHICLES

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Outline

NHTSA Research

- CAMP Automated Vehicle Research
  - Method To Determine Automation Level
  - High Level Safety Principles
- Objective Test Development
  - Framework
  - Use Cases – Examples
- Summary

CAMP AVR Project

- Project Started November 2013
- Project consisted six technical tasks
- Project Participants
  - Ford Motor Company
  - General Motors
  - Mercedes Benz
  - Nissan
  - Toyota Motors
  - Volkswagen Group of America
- Project Completed
  - Report in Final NHTSA Review

CAMP AVR Research

Objectives

- Develop functional descriptions of automation levels
- Develop list of potential driving automation features
- Develop a set of safety principles that apply by level
- Develop potential objective test methods as a framework for evaluating driving automation systems
- Coordinate with NHTSA
  - Human factors
  - Electronic control systems safety

Why Automation Levels Are Needed

- Critical safety discussions
  - Potential changes to driver’s role
  - Proper use of technology
- Common framework
  - Design
  - Customer education/training
  - Regulation
- Benefits to development, understanding and acceptance
  - Categorize technology based on functional attributes
  - Clarify driver’s role in proper usage

Automated Level Categorization Flow Chart for Automation Designers

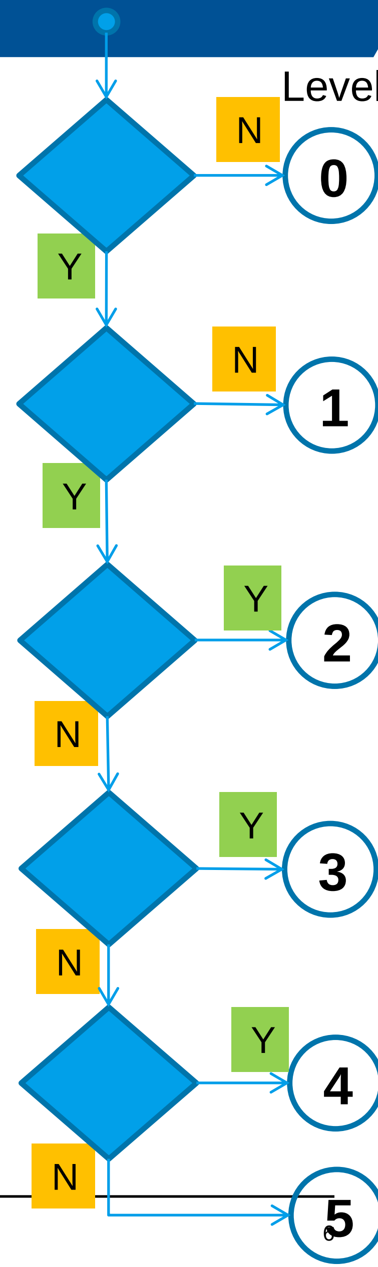
Does the feature perform sustained control of lateral **or** longitudinal motion to objects or events?

Does the feature perform both sustained **longitudinal and lateral control**?

Does the feature require **supervision** by the driver during its normal operation?

Does the feature rely on the driver to take over **(fallback)** if it is not operating normally?

Does the feature have a **limited** scope of operation?



Mapping Features to Levels using CAMP AVR Methodology

Driving Automation Methodology Question	Sustained Lateral **OR** Longitudinal control?	Sustained Lateral **AND** Longitudinal Control?	Driver supervision required?	Driver required outside normal operation?	Limited scope of operation?	
Driving Automation characteristic	Control to the external environment		Sensing and response	Fallback	Operational conditions	
Response to methodology question confirms level or proceeds to next question	Yes, move to next question		No, move to next question			
	No, stop at this level		Yes, stop at this level			
Driving Automation Level	**0**	**1**	**2**	**3**	**4**	**5**
Electronic Stability Control (ESC)	No ↑					
Conventional Cruise control	No ↑					
Adaptive cruise control (ACC)	Yes →	No ↑				
ACC with Lane Keeping (steering support)	Yes →	No ↑				
ACC with Lane Centering	Yes →	Yes →	Yes ↑			
Highway pilot	Yes →	Yes →	No →	Yes ↑		
Automated Parking System	Yes →	Yes →	No →	No →	Yes ↑	
Robotic Taxi	Yes →	Yes →	No →	No →	No →	↑

Development of Top-Level Safety Principles

A key deliverable of the AVR Consortium entailed

- The creation of a hazard analysis in order to generate top-level safety principles intended to effectively and succinctly cover the identified hazards inherent in driving automation levels 2-5

- The development of a set of solution-neutral, top-level, safety principles for each of the driving automation levels defined in a previous AVR task

- Establish (where possible) safety guidance for driving automation systems, while leaving it to the OEM/system designer to generate plausible solutions

Process to Develop Safety Principles

1. Identify Potential **Losses**

2. Identify Potential **Hazards**

3. Draw **Control Structure**

4. Identify **Undesired Control Actions**

5. Identify **Safety Constraints**
(to eliminate undesired control actions)

6. Aggregate constraints into over-arching **principles for each level**

Utilize previous definitions of automation levels throughout

Three Actors Engaged in Driving Automation

Vehicle Operator*

Driving Automation

Vehicle Systems

All three are necessary to describe how automation impacts the performance of the dynamic driving task (DDT)

* - *e.g., driver*

Summary of Safety Principles - I

Safety principle related to:	When automation is engaged at:			
	Level 2	**Level 3**	**Level 4**	**Level 5**
Driver/ Operator	assures operational readiness (SP 2.1 i)	← (SP 3.1)	← (SP 4.1)	← (SP 5.1)
	relied upon to avoid hazards, by completing the OEDR subtask and DDT (SP 2.1 ii)			
		activates automation for first time in drive cycle (SP 3.4)	← (SP 4.5)	← (SP 5.5)
		determines if vehicle failure occurs and takes control (SP 3.10 i)		
		understands that direct driver input will cause a transition to lower lever automation and driver will then control those inputs (SP 3.10 ii)		
		takes control when requested by automation (SP 3.10 iii)		
		understands that after automation request to take control, automation will only remain in control for a limited time (SP 3.10 iv)		
Vehicle systems	designed such that the driver is capable of fully performing DDT (lateral / longitudinal control and OEDR) (SP 2.2)	← (SP 3.2)	← Note - include if vehicle is capable of lower level automation	← Note - include if vehicle is capable of lower level automation

Summary of Safety Principles - II

Safety principle related to:	When automation is engaged at: Level 2	Level 3	Level 4	Level 5
Automation Controller (part 1)	arbitrate between defined driver inputs and driving automation commands by prioritizing the driver input (SP 2.3 i)	← (SP 3.3 i)		
	allow driver to take full control at any time (SP 2.3 ii)	← (SP 3.3 ii)		
	may verify define driver input before deactivating driving automation (SP 2.3 iii)	← (SP 3.3 iii)		
		provides persistent indication to driver of operation in high automation state (SP 3.5)	← Note - include if vehicle is capable of lower level automation	← Note - include if vehicle is capable of lower level automation
		provides indication to driver of request to transition to lower level automation (SP 3.6)	← Note - include if vehicle is capable of lower level automation	← Note - include if vehicle is capable of lower level automation
		competently performs the DDT within its operational design domain (SP 3.7 i)	← (SP 4.2 i)	competently performs the DDT in all domains (SP 5.2)

Overall Summary of Safety Principles

	Level 2	Level 3	Level 4	Level 5
Driver / Operator	assures operational readiness (SP 2.1 i)	← (SP 3.1)	← (SP 4.1)	← (SP 5.1)
	relied upon to avoid hazards, by completing the OEDR subtask and DDT (SP 2.1 ii)			
		activates automation for first time in drive cycle (SP 3.4)	← (SP 4.5)	← (SP 5.5)
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Vehicle systems	designed such that the driver is capable of fully performing DDT (lateral / longitudinal control and OEDR) (SP 2.2)	← (SP 3.2)	← Note - include if vehicle is capable of lower level automation	← Note - include if vehicle is capable of lower level automation
Automation	arbitrate between defined driver inputs and driving automation commands by prioritizing the driver input (SP 2.3 i)	← (SP 3.3 i)		
	allow driver to take full control at any time (SP 2.3 ii)	← (SP 3.3 ii)		
	may verify define driver input before deactivating driving automation (SP 2.3 iii)	← (SP 3.3 iii)		
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		competently performs the DDT within its operational design domain (SP 3.7 i)	← (SP 4.2 i)	competently performs the DDT in all domains(SP 5.2)
		prohibit entry into automated driving when domain is not achieved (SP 3.7 ii)	← (SP 4.2 ii)	
	vehicle/automation system single point failure shall not cause immediate loss of total control (SP 2.4)	← (SP 3.8)	designed such that any single failure does not lead to a hazardous situation (SP 4.3)	← (SP 5.3)
		before exiting domain or in advance of automation failure that impacts DDT performance, system shall transfer control to the driver (SP 3.9)	ability to engage minimal risk condition when necessary (SP 4.2-iii)	← (SP 5.2)
		verified driver inputs shall cause transition to lower level automation (SP 3.9 i)	may delay requests by operator to take over/stop automation when necessary to avoid identified hazards (SP 4.4)	← (SP 5.4)
		system shall maintain operational condition that affords reasonable transition time to driver (SP 3.9 ii)		

Automated Vehicles – Coming Soon

Near Term

- Level 2 type systems are starting to hit the market
    - Tesla Autopilot
    - GM Super Cruise (announced- 2017)
    - Others coming

Features

- Highway Driving Assist
- Traffic Jam Assist
- Park Assist

Objective Testing Framework

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Highway pilot	Yes →	Yes →	No →	Yes ↑		

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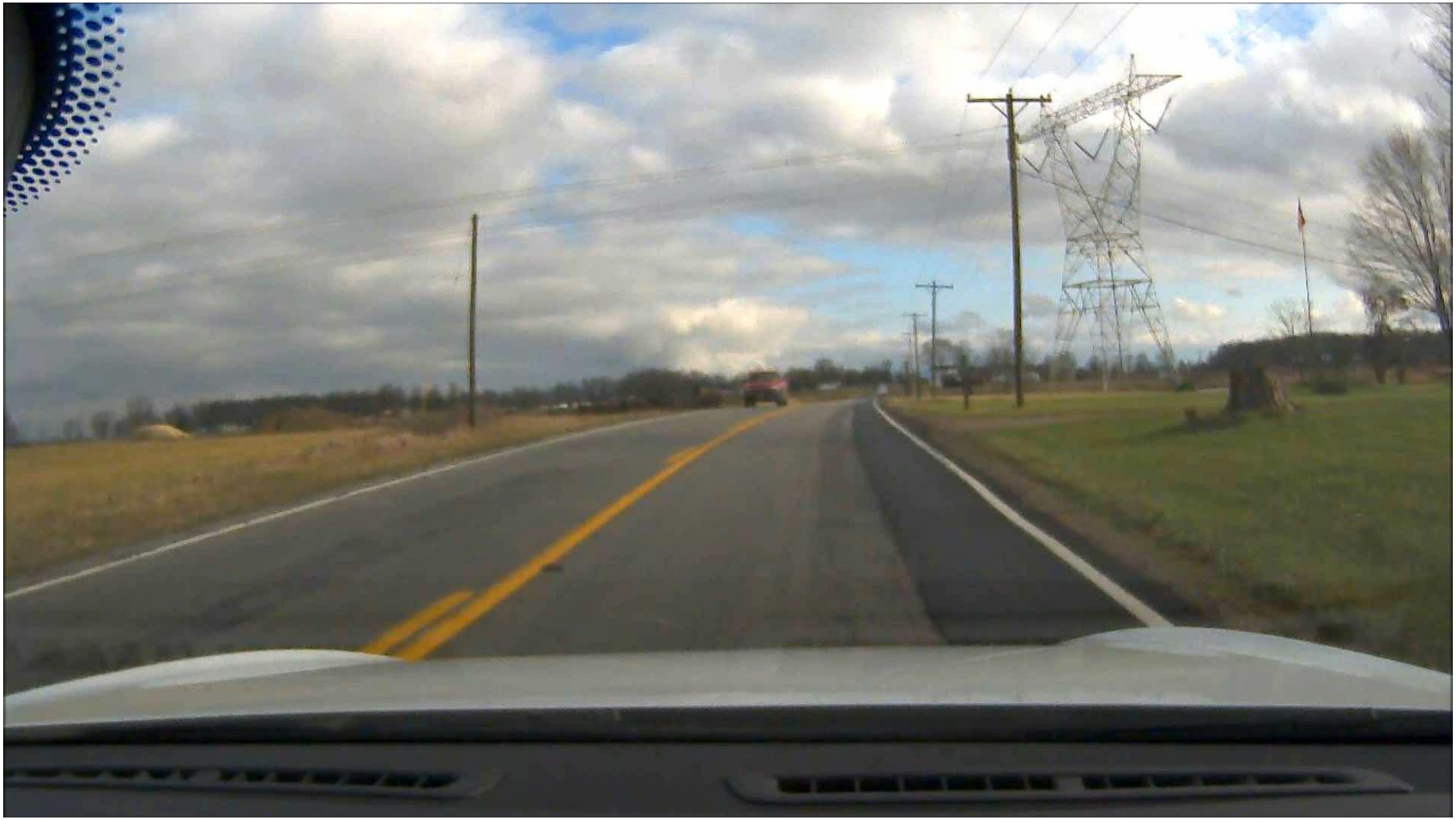
		before exiting domain or in advance of automation failure that impacts DDT performance, system shall transfer control	ability to engage minimal risk condition when necessary	← (SP 5.2)

Park Assist

Rural Driving



Intersection

Ping-Pong Lateral Control

Environment – Weather

Low Sun Angle

Summary

CAMP AVR

- Final Report will be released very soon

Future Objective Test Development

- Build on the framework developed in CAMP research
- Develop Objective tests based on the framework and use cases being studied by on road driving and crash cases
- Develop methods and determine factors that are critical for testing automated vehicles
  - Environment
  - Test course (curbs, road side features, etc.)
  - Surrogate Targets (multiple 3D robotic type targets)